IRRIGATED SUNFLOWERS IN NORTHWEST KANSAS: PRODUCTIVITY AND CANOPY FORMATION

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ABSTRACT

Sunflower was grown in a three year study (2009, 2010, and 2012) at the KSU Northwest Research-Extension Center at Colby, Kansas under a lateral move sprinkler irrigation system. Irrigation capacities were limited to not more than 1 inch every 4, 8, or 12 days but were scheduled only as needed as determined with a weather-based water budget. Achene (sunflower seed) yields and oil yield generally plateaued at the medium irrigation level. Dormant preseason irrigation increased achene yield and oil yield by 2% with most of this increase occurring in the extreme drought year, 2012. The optimum harvest plant population for sunflower in this study in terms of achene yield and oil yield was approximately 19,000 to 20,000 plants/acre.

INTRODUCTION

Sunflower is a crop of interest in the Ogallala Aquifer region because of its shorter growing season and thus lower overall irrigation needs. Sunflowers are thought to better withstand short periods of crop water stress than corn and soybeans and the timing of critical sunflower water needs is also displaced from those of corn and soybeans. Thus, sunflowers might be a good choice for marginal sprinkler systems and for situations where the crop types are split within the center pivot sprinkler land area.

Center pivot sprinkler irrigation (CP), the predominant irrigation method in the Ogallala region, presents unique challenges when used for deficit irrigation. Center pivot sprinkler irrigation cannot be effectively used to apply large amounts of water timed to a critical growth stage as can be done with surface irrigation methods. The CP systems also cannot efficiently use small frequent events to alleviate water stress as is the case with subsurface drip irrigation (SDI). Thus with CP systems, it is important that available soil water in storage be correctly managed temporally in terms of additions and withdrawals so that best crop production can be achieved both economically and water-wise. Three easy ways to control irrigation water additions are irrigation capacity, preseason management, and the season initiation date. Withdrawals can be partially managed by plant population. This study examined sunflower production using the three methods of controlling irrigation additions for three different targeted plant populations.

PROCEDURES

The study was conducted from 2009 through 2012 at the KSU Northwest Research-Extension Center at Colby, Kansas under a lateral move sprinkler irrigation system. However, data from 2011 is excluded due to a devastating hail storm that destroyed the crop. Key agronomic characteristics of the annual tests are shown in Table 1.

Table 1. Agronomic characteristics of an irrigated sunflower study conducted at the KSU Northwest Research-Extension Center, Colby, Kansas, 2009-2012. Data from 2011 are excluded due to devastating hail storm.

Characteristic	**2009**	**2010**	**2012**
Hybrid	Triumph S671[1]	Triumph S671	Triumph S671
Planting date	June 18	June 16	June 13
Emergence date	June 25	June 24	June 26
Harvest date	October 16	October 13	October 8
Rainfall, emergence to maturity (inches)	9.89	7.32	5.25
Preseason irrigation (inches)	5.0	5.0	9.2
First seasonal irrigation	July 27	July 25	July 25
Last seasonal irrigation	September 15	September 15	September 23

Whole plot treatments were sprinkler irrigation capacities of 1 inch every 4, 8, or 12 days as limited by ET-based water budget irrigation scheduling. An additional whole plot irrigation factor was the addition or no addition of dormant preseason irrigation resulting in a total of 6 different irrigation treatments. The target preseason irrigation amount for those plots receiving it was 5 inches, but in 2012 a total of 9.2 inches of preseason irrigation was applied due to an application error. Three targeted plant populations 18,000, 23,000, or 28,000 plants/acre were superimposed on the whole plots for a grand total of 108 subplots. Irrigation amounts were 1 inch applied as needed, but limited by the imposed capacity and the water budget irrigation schedule. The whole plots (6 reps) were in a randomized complete block (RCB) design.

Soil water was measured periodically in each plot each crop season with a neutron probe to a depth of 8 feet in one foot increments. Crop water use was calculated as the sum of changes in soil water between emergence and physiological maturity, precipitation and irrigation amount. Crop water productivity (WP, also known as water use efficiency) was calculated as the achene yield in lbs/acre divided by the total crop water use in inches.

At R6 development stage and to maturity (R9 development stage), sunflower achene moisture content, dry mass and oil content were measured by collecting six achenes from each of five representative plants, semi-weekly. At maturity, sunflower heads were hand harvested from a representative sample area and threshed for yield and yield component determinations.

Leaf area index (LAI) was quantified, approximately bi-weekly, by a non-destructive light transmission technique (Welles, 1991; LAI-2000 Plant Canopy Analyzer[i]). Three sets of four below-canopy measurements were each referenced to an above-canopy measurement, minimizing sensor exposure to direct (beam) irradiance. Readings were screened against apparent transmittance ratios exceeding 1 using the manufacturer's software, FV2000. An inverse solution to a model of light transmission through a vegetative canopy, provided by the manufacturer, was used to quantify apparent LAI.

Growing degree days (GDD) were calculated from daily temperature extremes (Equation 1) recorded at the NWREC weather station, using a mercury thermometer.

$$GDD = \frac{T_{max} - T_{min}}{2} - T_b \qquad \text{Equation 1}$$

Upper and lower limits to temperature extremes were 34 ^{o}C and 4 ^{o}C (93 ^{o}F and 39 ^{o}F), respectively. Cumulative GDD (cGDD) was computed by summation of GDD, commencing from planting date.

Statistical analysis utilized analysis of variance (ANOV) and analysis of covariance (ANCOV). Repeated measure of LAI and maximum LAI observed in a year were analyzed by ANOV, using Proc GLM from SAS Institute. Seasonal trends in LAI and were analyzed by ANCOV using third order linear terms of cGDD or days after planting (DAP) as covariates.

RESULTS

Weather Conditions

The crop year 2009 was very cool and wet and irrigation needs were low. In-season irrigation amounts for the 1 inch every 4 and 8 days treatments were 7.68, 6.72, and 4.80 inches, respectively. During the period April through October every month had above normal precipitation and between crop emergence and crop maturity the total precipitation was 9.89 inches.

The early portion of the crop year 2010 was wet and irrigation needs were lower than normal. However, later in season, it was extremely dry with only 1.08 inches of precipitation occurring between August 4 and crop maturity on October 11. Precipitation during the sunflower growing period totaled 7.32 inches. In-season irrigation amounts were 11.52, 6.72, and 4.8 inches for the irrigation capacities limited to 1 inch/4 days, 1 inch/8 days, and 1 inch/12 days, respectively. The 2010 sunflower irrigation amounts appear to be approximately 1 inch less than normal as estimated from long term (1972-2005) irrigation scheduling simulations conducted at Colby, Kansas.

Extreme drought conditions existed for all of 2012 and only 5.25 inches of precipitation occurred during the sunflower growing period. Additionally, temperatures of 100°F or greater occurred on 20 days between June 26 and August 15. Crop establishment may have been negatively affected by excessively hot temperatures (99 to 104°F) that occurred for the entire period between planting and emergence even though small amounts of irrigation kept sufficient amounts of water in the seed zone. Sunflower plant populations at harvest in 2012 averaged approximately 75% of levels that occurred in 2009 and 2010. In-season irrigation amounts were 13.94, 8.18, and 6.26 inches for the irrigation capacities limited to 1 inch/4 days, 1 inch/8 days and 1 inch/12 days, respectively.

Summarizing the weather conditions, the crop year 2009 was cooler and wetter than normal, the crop year 2010 was approximately normal though a severe drought began in early August, and the crop year 2012 was extremely hot and dry.

Crop Yields and Yield Components

The addition of dormant preseason irrigation did not significantly increase yields in any of the three years (Tables 2, 3, and 4), but did increase achene yield and oil yield by 2%, when all years were analyzed together. Most of the increase in yield for preseason irrigation occurred in the extreme drought year, 2012. Preseason irrigation did significantly increase heads/plant in 2009 and harvest plant population in 2010, but these differences were only about 3% greater. There were no statistically significant differences in yield attributable to irrigation capacity in 2009 and 2012, but increased irrigation capacity did increase achene yield in 2010. Increased irrigation capacity tended to numerically increase achene and oil yield in all three years up through the 1 inch/8 day irrigation capacity but tended to have less or no response above that level. (Figure 1). Achene yields were lower in 2010 than in 2009 and 2012, but still were towards the upper range of yields for the region.

There were no plant population effects on achene yield in 2009, but increased plant population decreased achene yield in 2010 and increased achene yield in 2012 (Tables 2, 3 and 4). The difference between 2010 and 2012 responses is probably related to the differences in harvest plant populations between the two years. As indicated in earlier section, crop establishment was poor in 2012. Harvest plant populations in 2010 averaged 19,263, 23,426, and 26,257 plants/acre for the three respective targets as compared to the much lower 2012 values of 14,452, 17,530, and 19,781 plants/acre. Increasing plant population significantly decreased achenes/head in both 2009 and 2010 but had no consistent effect in 2012, once again probably because harvest plant populations were so low (Tables 2, 3 and 4). Increasing plant population significantly decreased achene mass and significantly increased achene oil content (percentage) in all three years. Within a given year average differences in oil content ranged from 1 to 2% as affected by plant population. Harvest plant populations above 19,000 to 20,000 plants/acre resulted in reduced achene yields and oil yields, but oil content was greatest at the greatest plant population in all three years (Figure 2).

Crop Water Use and Water Productivity

In-season crop water use was significantly increased by increased irrigation in all three years (Tables 2, 3, and 4 and Figure 1). However, crop water productivity (WP) was significantly reduced by increased irrigation in all three years. Irrigation amounts ranged from 4.80 to 7.68 inches in 2009, 4.80 to 11.52 inches in 2010, and 6.26 to 13.94 inches in 2012. Soil water depletion decreased with irrigation capacity (data not shown).

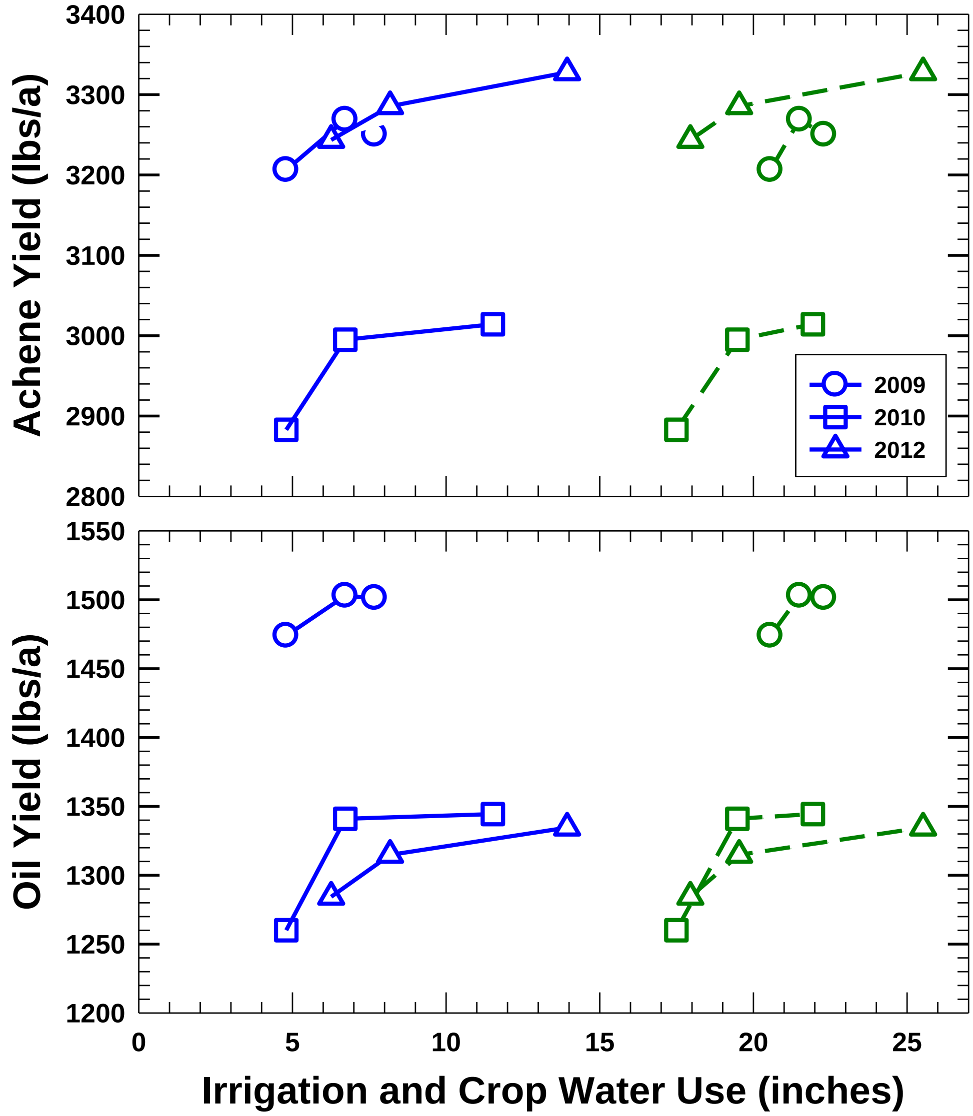

Figure 1. Achene yield and oil yield as related to irrigation amount and total crop water use in a sprinkler irrigated sunflower study, KSU Northwest Research-Extension Center, Colby, Kansas, 2009-2012. Note: Irrigation responses in blue unbroken lines and crop water use responses in green dashed lines.

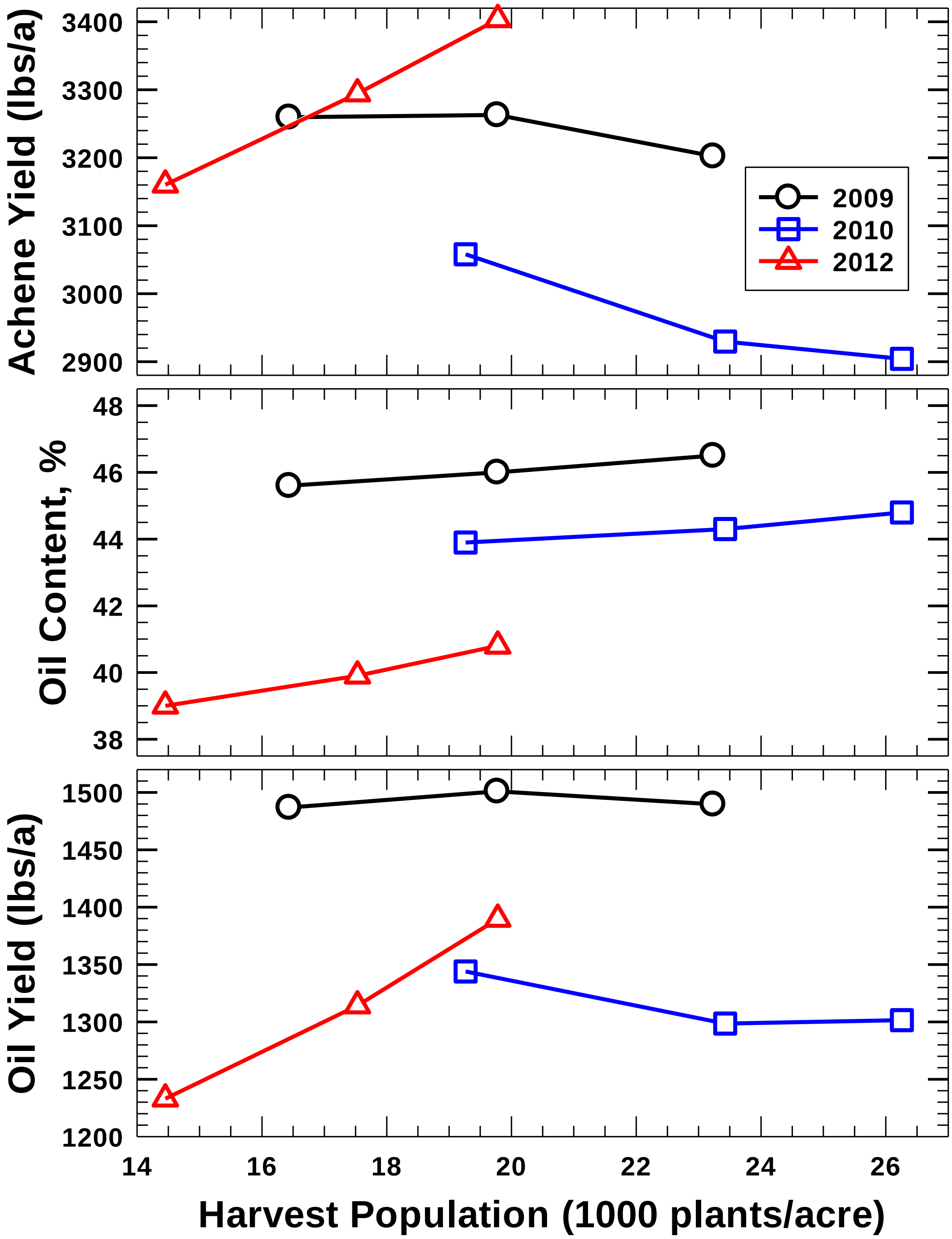

Figure 2. Achene yield, oil content, and oil yield as related to harvest plant population in a sprinkler irrigated sunflower study, KSU Northwest Research-Extension Center, Colby, Kansas, 2009-2012.

Table 2. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2009, KSU Northwest Research-Extension Center, Colby Kansas.

Irrigation capacity	Preseason irrigation	Targeted plant population (1000 p/a)	Yield (lb/a)	Harvest plant population (p/a)	Heads /plant	Achenes /head	Achene Mass (mg)	Achene Oil%	Water use (inches)	Water Productivity (lb/acre-in)
1 in/4 d (7.68 in)	None	18	3266	16262	0.94	2114	46.6	45.6	21.94	149
		23	3324	20183	0.92	2043	40.2	46.2	22.49	148
		28	3109	23813	0.93	1720	37.2	46.6	22.10	141
		Mean	3233	20086	0.93	1959	41.3	46.2	22.18	146
	5 inches	18	3229	16553	0.94	2155	44.3	45.7	22.06	146
		23	3326	20328	0.93	1919	42.0	46.3	22.24	150
		28	3246	22942	0.99	1728	39.3	46.8	22.96	141
		Mean	3267	19941	0.95	1934	41.9	46.2	22.42	146
Mean 1 inch/4 days			**3250**	**20013**	**0.94**	**1947**	**41.6**	**46.2**	**22.30 c**	**146 b**
1 in/8 d (6.72 in)	None	18	3376	16698	0.95	2259	43.4	45.7	21.08	161
		23	3189	20183	0.95	1893	40.4	46.0	21.29	150
		28	3081	22506	0.96	1790	37.5	46.5	21.89	141
		Mean	3215	19796	0.95	1981	40.4	46.1	21.42	151
	5 inches	18	3427	16553	0.99	2214	42.8	45.0	21.56	159
		23	3208	19312	0.96	1934	40.6	46.1	21.21	151
		28	3332	22506	1.01	1766	38.4	46.6	22.01	152
		Mean	3322	19457	0.99	1971	40.6	45.9	21.60	154
Mean 1 inch/8 days			**3269**	**19626**	**0.97**	**1976**	**40.5**	**46.0**	**21.51 b**	**152 a**
1 in/12 d (4.80in)	None	18	3158	16408	0.93	2198	42.8	45.7	20.38	155
		23	3186	19457	0.96	1923	40.3	45.9	20.75	154
		28	3168	24103	0.91	1728	38.3	46.5	20.75	153
		Mean	3171	19989	0.93	1950	40.5	46.0	20.63	154
	5 inches	18	3100	16117	0.97	2127	42.3	46.1	20.36	152
		23	3345	19166	0.96	1985	41.9	45.6	20.41	164
		28	3279	23522	0.94	1758	38.4	46.2	20.68	159
		Mean	3241	19602	0.96	1957	40.8	45.9	20.48	158
Mean 1 inch/12 days			**3206**	**19796**	**0.95**	**1953**	**40.7**	**46.0**	**20.56 a**	**156 a**
Study-Wide Mean			**3242**	**19812**	**0.95**	**1959**	**40.9**	**46.0**	**21.45**	**151**
Preseason Irrigation	**None**		**3206**	**19957**	**0.94 a**	**1963**	**40.7**	**46.1**	**21.41**	**150**
	5 inches		**3277**	**19667**	**0.97 b**	**1954**	**41.1**	**46.0**	**21.50**	**153**
Target plant population (1000 p/a)		**18**	**3260**	**16432 a**	**0.95**	**2178 a**	**43.7 a**	**45.6 c**	**21.23**	**154 a**
		23	**3263**	**19771 b**	**0.95**	**1950 b**	**40.9 b**	**46.0 b**	**21.40**	**153 a**
		28	**3203**	**23232 c**	**0.96**	**1748 c**	**38.2 c**	**46.5 a**	**21.73**	**148 b**

Shaded items within a column are significantly different at P<0.05 when followed by a different lower-cased letter.

Table 3. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2010, KSU Northwest Research-Extension Center, Colby Kansas.

Irrigation capacity	Preseason irrigation	Targeted plant population (1000 p/a)	Yield (lb/a)	Harvest plant population (p/a)	Heads /plant	Achenes /head	Achene Mass (mg)	Achene Oil%	Water use (inches)	Water Productivity (lb/acre-in)
1 in/4 d (11.52 in)	None	18	3172	20038	0.94	1916	40.4	44.2	22.69	141
		23	2919	23668	0.89	1631	38.6	44.7	22.74	128
		28	2946	27007	0.85	1570	37.4	45.0	23.32	127
		Mean	3012	23571	0.90	1706	38.8	44.6	22.92	132
	5 inches	18	3000	19166	0.93	1845	42.3	43.8	20.99	143
		23	3062	23958	0.95	1646	37.3	44.7	21.15	146
		28	2987	25265	0.95	1597	36.1	45.3	20.72	145
		Mean	3172	20038	0.94	1916	40.4	44.2	22.69	141
Mean 1 inch/4 days			**3014 a**	**23184**	**0.92**	**1701**	**38.7**	**44.6 a**	**21.93 a**	**138 c**
1 in/8 d (6.72 in)	None	18	3043	19602	0.92	1893	41.0	44.5	19.63	157
		23	2989	23377	0.98	1668	36.1	44.6	20.01	150
		28	3004	25700	0.97	1563	35.7	45.3	19.36	156
		Mean	3012	22893	0.96	1708	37.6	44.8	19.66	154
	5 inches	18	3091	18440	0.98	1912	40.6	44.3	19.01	164
		23	2892	23087	0.93	1647	37.2	44.7	19.31	151
		28	2951	25410	0.98	1506	36.3	45.3	19.58	152
		Mean	3043	19602	0.92	1893	41.0	44.5	19.63	157
Mean 1 inch/8 days			**2995 a**	**22603**	**0.96**	**1698**	**37.8**	**44.8 a**	**19.48 b**	**155 b**
1 in/12 d (4.80 in)	None	18	2983	19312	0.96	1868	39.4	43.2	17.25	175
		23	2886	23522	0.96	1715	34.4	43.6	16.85	175
		28	2705	27588	0.88	1480	34.4	44.0	17.10	159
		Mean	2858	23474	0.93	1688	36.1	43.6	17.07	170
	5 inches	18	3059	19021	0.95	1983	39.0	43.7	18.12	170
		23	2831	22942	0.94	1613	37.0	43.6	17.99	158
		28	2833	26572	0.91	1511	35.5	44.1	17.67	162
		Mean	2908	22845	0.93	1702	37.2	43.8	17.93	163
Mean 1 inch/12 days			**2883 b**	**23159**	**0.93**	**1695**	**36.6**	**43.7 b**	**17.50 c**	**167 a**
Study-Wide Mean			**2964**	**22982**	**0.94**	**1698**	**37.7**	**44.4**	**19.64**	**153**
Preseason Irrigation	**None**		**2961**	**23313 a**	**0.93**	**1700**	**37.5**	**44.3**	**19.88**	**152**
	5 inches		**2967**	**22651 b**	**0.95**	**1695**	**37.9**	**44.4**	**19.39**	**155**
Target plant population (1000 p/a)		**18**	**3058 a**	**19263 c**	**0.94**	**1903 a**	**40.5 a**	**43.9 c**	**19.61**	**158 a**
		23	**2930 b**	**23426 b**	**0.94**	**1653 b**	**36.8 b**	**44.3 b**	**19.67**	**151 b**
		28	**2904 b**	**26257 a**	**0.92**	**1538 c**	**35.9 b**	**44.8 a**	**19.62**	**150 b**

Shaded items within a column are significantly different at P<0.05 when followed by a different lower-cased letter.

Table 4. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2012, KSU Northwest Research-Extension Center, Colby Kansas.

Irrigation capacity	Preseason irrigation	Targeted plant population (1000 p/a)	Yield (lb/a)	Harvest plant population (p/a)	Heads /plant	Achenes /head	Achene Mass (mg)	Achene Oil%	Water use (inches)	Water Productivity (lb/acre-in)
1 in/4 d (13.94 in)	None	18	3145	14956	1.00	1555	61.6	39.4	24.82	126
		23	3265	16988	0.99	1497	59.6	39.8	25.89	126
		28	3315	21635	0.87	1750	52.9	41.6	24.86	133
		Mean	3242	17860	0.95	1601	58.0	40.3	25.19	129
	9.2 inches	18	3183	14985	1.00	1666	58.1	39.1	25.33	126
		23	3448	17424	0.99	1572	58.2	40.3	25.64	134
		28	3662	19689	0.99	1599	53.7	40.3	26.79	137
		Mean	3431	17366	0.99	1612	56.6	39.9	25.92	132
Mean 1 inch/4 days			**3328**	**17635**	**0.97**	**1606**	**57.4**	**40.1**	**25.52**	**130 c**
1 in/8 d (8.18 in)	None	18	3191	13939	1.00	1717	62.6	38.9	20.45	157
		23	3160	16698	0.99	1494	58.8	39.6	20.23	156
		28	3423	19747	1.00	1439	55.3	40.8	20.80	165
		Mean	3258	16795	1.00	1550	58.9	39.7	20.49	159
	9.2 inches	18	3148	14375	1.00	1544	65.2	39.2	18.61	172
		23	3310	17569	0.98	1495	59.4	40.1	18.37	181
		28	3480	19747	1.00	1414	58.0	41.5	18.75	187
		Mean	3313	17230	0.99	1484	60.9	40.3	18.58	180
Mean 1 inch/8 days			**3286**	**17013**	**0.99**	**1517**	**59.9**	**40.0**	**19.54**	**169 b**
1 in/12 d (6.26 in)	None	18	3237	14462	1.00	1610	63.8	39.1	17.41	188
		23	3126	17772	0.98	1280	64.9	39.9	17.18	183
		28	3121	18121	1.00	1490	54.5	40.0	17.43	180
		Mean	3161	16785	0.99	1460	61.0	39.7	17.34	183
	9.2 inches	18	3074	14084	1.00	1440	70.1	38.4	18.52	168
		23	3487	18992	0.99	1478	57.5	39.8	18.47	191
		28	3417	19457	0.97	1410	59.3	40.5	18.47	186
		Mean	3316	17424	0.99	1440	62.6	39.5	18.49	181
Mean 1 inch/12 days			**3244**	**17125**	**0.99**	**1450**	**61.9**	**39.6**	**17.95**	**182 a**
Study-Wide Mean			**3286**	**17251**	**0.99**	**1525**	**59.7**	**39.9**	**20.99**	**161**
Preseason Irrigation	**None**		**3224**	**17168**	**0.98**	**1541**	**59.2**	**39.9**	**21.22**	**156**
	9.2 inches		**3350**	**17337**	**0.99**	**1508**	**60.2**	**39.9**	**20.75**	**166**
Target plant population (1000 p/a)		**18**	**3160 b**	**14452 c**	**1.00**	**1586**	**63.7 a**	**39.0 c**	**20.83**	**156**
		23	**3294 ab**	**17530 b**	**0.99**	**1472**	**59.7 b**	**39.9 b**	**21.01**	**161**
		28	**3404 a**	**19781 a**	**0.97**	**1515**	**55.7 c**	**40.8 a**	**21.13**	**165**

Shaded items within a column are significantly different at P<0.05 when followed by a different lower-cased letter.

Canopy formation

Seasonal changes in sunflower canopy are shown in Figure 3. Preseason irrigation amounts of 9" resulted in greater leaf area from mid-vegetative growth through mid-seed fill in 2012. Canopy formation and senescence occurred relatively earlier in 2010 than 2009 and 2012, which were similar. Canopy formation was greatest in 2010 and least in 2012.

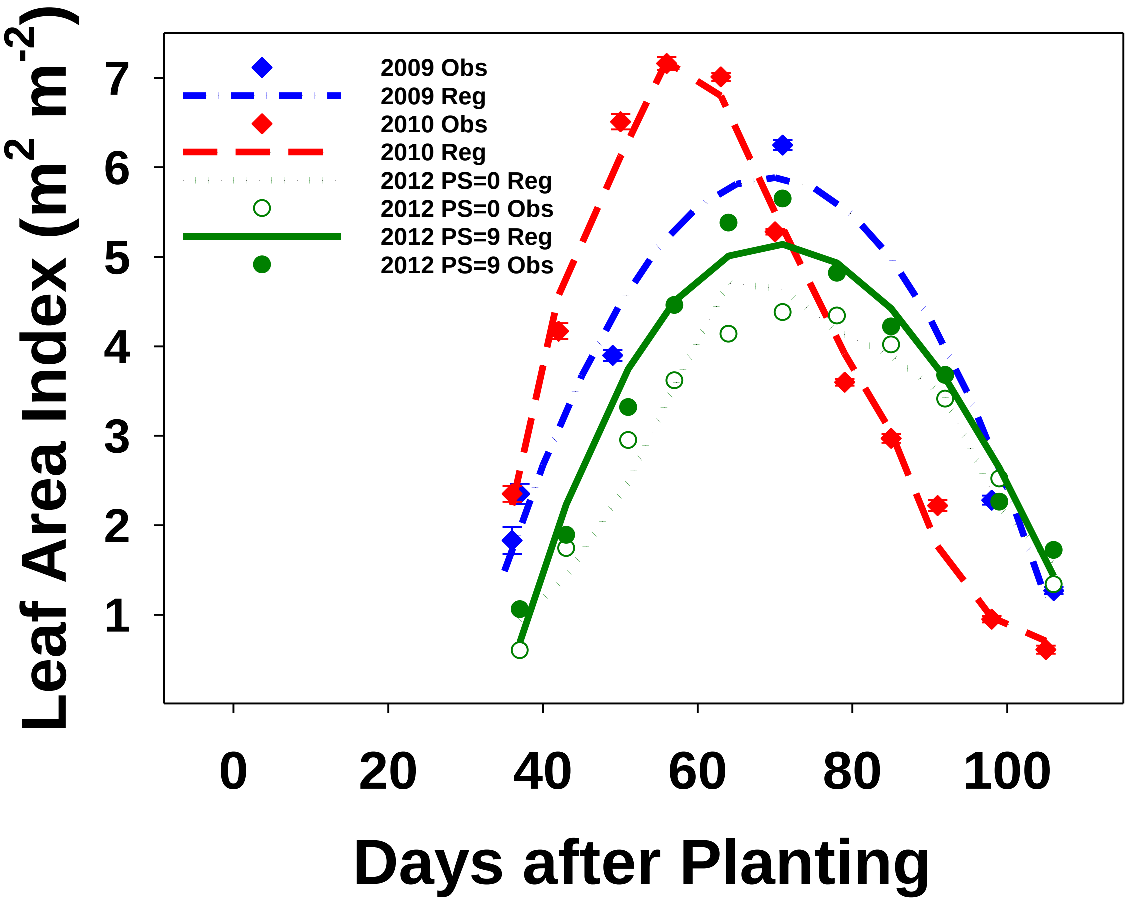

Figure 3. Seasonal trends in canopy formation and senescence are shown in relation to days after planting for a sprinkler irrigated sunflower study, KSU Northwest Research-Extension Center, Colby, Kansas, 2009-2012. Note that symbols represent field observations and lines represent a trend model. Preseason irrigation effects (0" or 9") were detected in 2012.

Yield formation

Achene water content, oil content, and dry mass changes during the season are shown in Figure 4. Achene water contents were greatest for the initial sampling dates and declined throughout the seed fill period. In 2010, achene water content was slightly greater for the largest irrigation capacity. Oil content of achenes increased from the R6 to R8 development stage, remaining consistent through maturity; slightly greater oil contents were observed for the smallest irrigation capacity in 2010. Oil contents from late-season samples appeared similar, though the harvest samples from a larger sampling area (Tables 2, 3, and 4) indicate greatest oil content in 2009

(46.0%) and smallest oil content in 2012 (39.9%). The change in achene mass in 2012, relative to the initial sampling date, was approximately twice that observed in 2009 and 2010; this likely reflected effects of the reduced stands discussed earlier. Preseason irrigation resulted in larger achenes in 2009, but smaller achenes in 2012, likely reflecting differences in achenes per head. Cumulative growing degree days appears to provide an inconsistent measure of time relative to onset and completion of the yield formation periods, as indicated by the staggered onset and duration of sampling intervals over the three growing seasons (Figure 4).

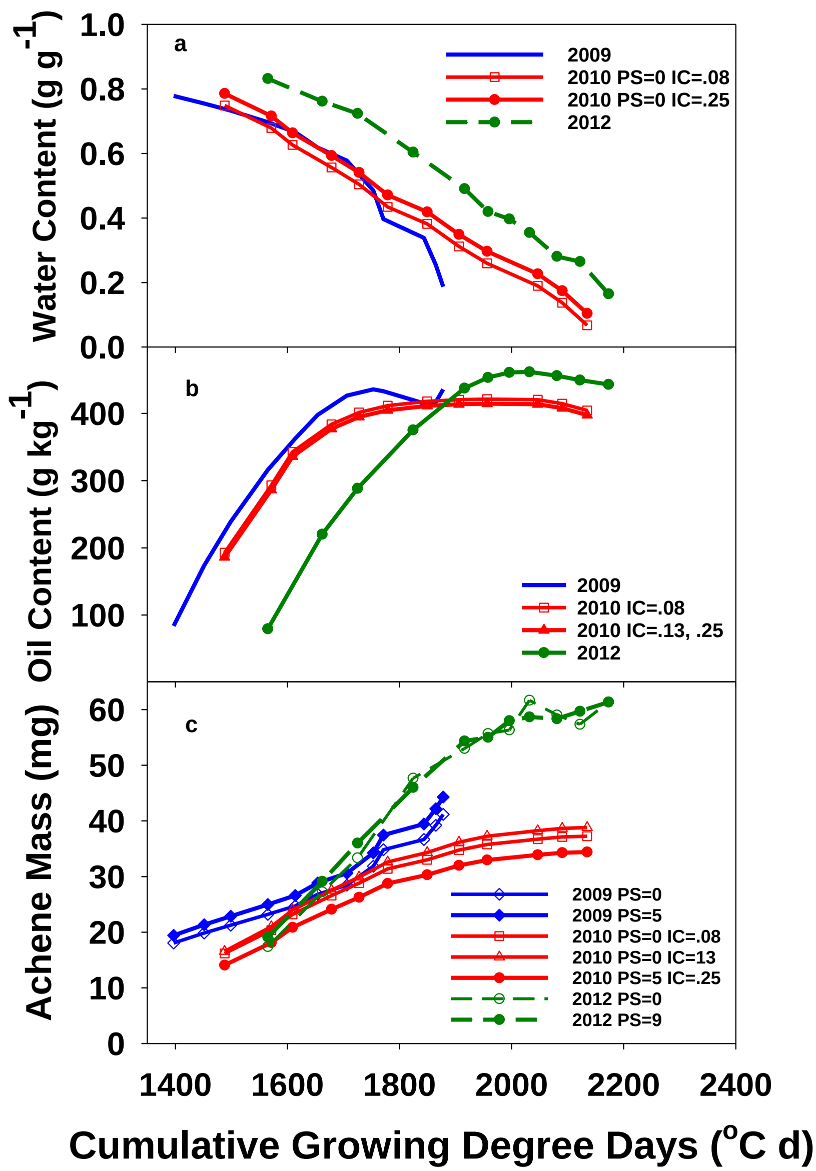

Figure 4. Trends in sunflower achene water content (a), oil content (b) and dry achene mass (c) are shown in relation to cumulative growing degree days from planting. This sprinkler irrigated sunflower study was conducted at KSU Northwest Research-Extension Center, Colby, Kansas, 2009-2012. Preseason irrigation (PS) and irrigation capacity (IC) effects, which were detected in the study, are indicated.

SUMMARY AND CONCLUSION

Sunflower was grown under sprinkler irrigation in Colby, Kansas for three very different crop years (2009, cool and wet year; 2010 near normal overall but very dry after flowering; and 2012, a severe drought year with high temperatures). Irrigation capacities were limited to not more than 1 inch every 4, 8, or 12 days but irrigation events were scheduled only as needed as determined with a weather-based water budget. Seasonal trends indicated earlier canopy formation, greatest canopy extent, and earliest senescence in 2010; least canopy extent developed in 2012. Seasonal trends were similar for achene water content (decreasing through maturity), oil content, and achene mass (increasing through R8 development stage). Achene yield was only statistically increased by irrigation in 2010, but tended to increase numerically up through the medium irrigation level (1 inch/8 days) in all three years. Similarly, oil yield plateaued at the medium irrigation level. Dormant preseason irrigation increased achene yield and oil yield by 2%. The optimum harvest plant population for sunflower in this study in terms of achene yield and oil yield was approximately 19,000 to 20,000 plants/acre.

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[i] Mention of tradenames is for informational purposes only and does not constitute endorsement by the authors or by the institutions they serve.